DOCUMENT RESUME

ED 071 893 SE 015 530

TITLE	Project Physics Tests 3, The Triumph of Mechanics.
INSTITUTION	Harvard Univ., Cambridge, Mass. Harvard Project Physics.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO	BR-5-1038
PUB DATE	68
CONTRACT	OEC-5-10-058
NOTE	24p.; Authorized Interim Version
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Achievement Tests; Heat; Instructional Materials; Kinetic Molecular Theory; *Kinetics; *Physics; Secondary Grades; *Secondary School Science; *Testing; Thermodynamics
IDENTIFIERS	Harvard Project Physics

ABSTRACT

Test items relating to Project Physics Unit 3 are presented in this booklet. Included are 70 multiple-choice and 20 problem-and-essay questions. Concepts of mechanics are examined on energy, momentum, kinetic theory of gases, pulse analyses, "heat death," water waves, power, conservation laws, normal distribution, thermodynamic laws, and wave reflection, refraction, interference, and diffraction. Suggestions are made for time consumption in answering some items. Besides directions and illustrations for explanation purposes, related physical constants, units, and equations are provided. The work of Harvard Project Physics has been financially supported by: the Carnegie Corporation of New York, the Ford Foundation, the National Science Foundation, the Alfred P. Sloan Foundation, the United States Office of Education, and Harvard University. (CC)

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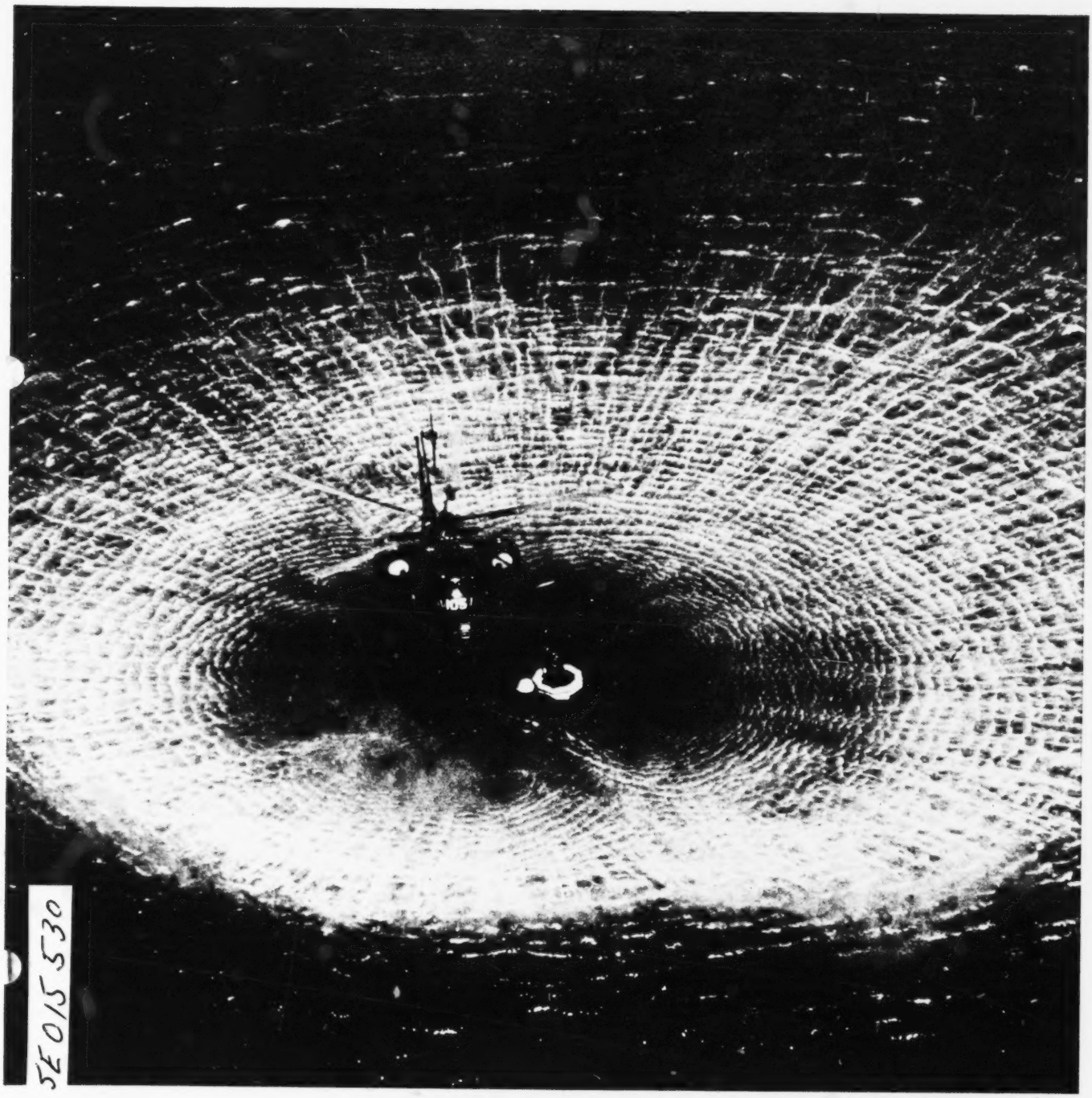
Project Physics **Tests**

An Introduction to Physics

The Triumph of Mechanics



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Consult the Project Physics text for a partial list of the current and recent staff, consultants and advisory committee.

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Directions

This test consists of fifteen multiple-choice questions and six problem-and-essay questions divided into two groups. Answer ALL multiple-choice questions by marking the letter corresponding to the one best answer. Answer THREE of the problem-and-essay questions from Group One and ONE from Group Two. Spend about 15 minutes on the multiple-choice questions, 5 minutes on each of the problem-and-essay questions from Group One and 10 minutes on the problem-and-essay question from Group Two.

NOTE:

The numerical values of some physical constants, definitions of certain units, and equations that may be useful in this test are given below.

Physical Constant:

Acceleration of gravity $a_g = 10$ meters/second^2

Physical Units:

$$1 \text{ newton} = \frac{1 \text{ kilogram-meter}}{\text{second}^2}$$

$$1 \text{ joule} = 1 \text{ newton-meter or } \frac{1 \text{ kilogram-meter}^2}{\text{second}^2}$$

$$1 \text{ watt} = \frac{1 \text{ joule}}{\text{second}}$$

Equations:

$v = at$

$d = \frac{1}{2}at^2$

$\vec{F} = m\vec{a}$

$\vec{p} = m\vec{v}$

$KE = \frac{1}{2}mv^2$

$\Delta(PE)_{(grav)} = ma_g d$

$W = F_{\parallel} d.$

$\text{power} = \frac{W}{t}$

$T = \frac{1}{f}$

$v = f\lambda$

1. When the speed of a car is doubled, the car's

A. kinetic energy is doubled.
B. potential energy is doubled.
C. momentum is doubled.
D. acceleration is doubled.
E. inertia is doubled.

2. A freight car of mass 2.0×10^4 kilograms standing at rest is rammed by a loaded tank car with a mass of 3.0×10^4 kilograms. After the collision, the two cars are locked together and move off at a speed of 0.60 meters per second. What was the speed of the tank car before the collision?

A. 0.20 m/sec
B. 0.75 m/sec
C. 1.0 m/sec
D. 3.6 m/sec
E. 4.0 m/sec

3. When two waves pass the same point at the same time, their amplitudes at this point always

A. cancel.
B. reflect off each other.
C. reinforce each other.
D. hinder each other's progress.
E. superpose.

4. In a certain medium the speed of a group of waves has a fixed value. If the frequency of the waves is doubled, their wavelength will be

A. 4 times its original value.
B. 2 times its original value.
C. unchanged.
D. ½ its original value.
E. ¼ its original value.

5. Which of the following three quantities have the same magnitude just before and just after a perfectly elastic collision?

1. momentum
2. kinetic energy
3. total energy

A. 1 only
B. 2 only
C. 3 only
D. 2 and 3 only
E. 1, 2, and 3

Questions 6, 7, and 8 are the names of scientists who made early significant contributions to the study of thermodynamics. Select the one statement that best describes a contribution of the particular scientist.

A. The pressure of a gas is proportional to the square of the speed of its molecules.
B. Heat is a form of energy.
C. The speeds of molecules in a gas follow a statistical law.
D. In an elastic collision, momentum is conserved.
E. The process of equalization of temperatures by the flow of heat from hot to cold bodies is always taking place in nature.

6. Joule

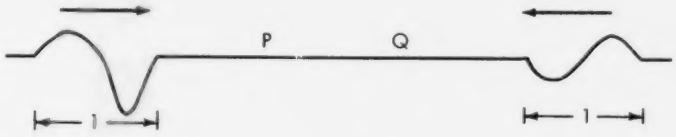
7. Carnot

8. Maxwell

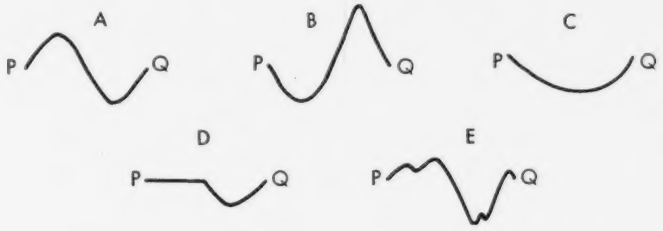
9. A girl lifts a bowling ball from the floor and places it on a rack. If you know the weight of the ball, what else must you know in order to calculate the work she does on the ball?

A. mass of the ball
B. value of a_g
C. height of the rack
D. the time required
E. nothing else

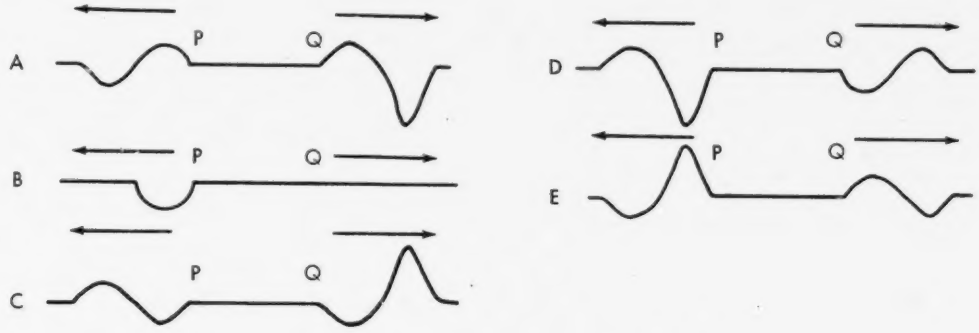
Questions 10 and 11 refer to the following statement and diagram. Two wave pulses, each of length 1, are traveling toward each other along a rope as illustrated in the diagram below.



10. When both waves are entirely in the region between P and Q, the shape of the rope will be



11. Just after both wave pulses have passed the region between P and Q, the shape of the rope will be



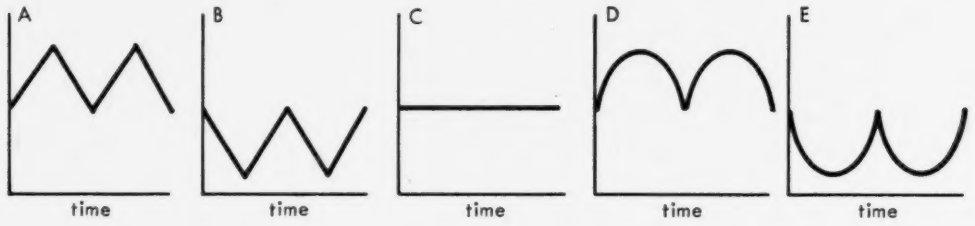
12. The prediction of a "heat death" is based on the principle which states that

A. the law of conservation of energy applies only to closed systems.
B. at some time in the future, the energy of the universe will become zero.
C. all bodies in the universe will eventually reach the same temperature by exchanging heat with each other.
D. it is impossible to think of a system in which energy is completely conserved.

13. The law of normal distribution applies in ALL EXCEPT ONE of the following cases. Which is the exception?

A. the heights of a large number of 25-year-old maple trees in a certain forest
B. the speed of a falling object measured at many different times during the object's fall
C. the scores on a test taken by a large number of students.

The following graphs refer to questions 14 and 15.



At time t = zero a pendulum is set into motion by releasing the pendulum bob at a certain height.

14. Which of the graphs best represents the variation of the bob's kinetic energy with time?

15. Which of the graphs best represents the variation of potential energy with time?

PROBLEM-AND-ESSAY QUESTIONS

Group One

Answer THREE of the following five questions.

1. A vibrating rod generates waves in a pool of water. Describe any change in the water waves that would occur if the rod's frequency of vibration was increased.

2. What is the magnitude of the momentum of

   a. a baseball (mass = 0.14 kilogram) as it moves at 30 meters per second?
   b. a 0.22 caliber bullet (mass = 2.0×10^{-3} kilograms) as it leaves the barrel of a pistol at a speed of 300 meters per second?

3. Describe the model of a gas developed in the kinetic theory of gases.

4. What is the power of a motor that can lift a 100-newton weight a height of 10 meters in 50 seconds?

5. S_1 and S_2 are two in-phase periodic sources of waves with wavelength λ. What conditions determine whether point P lies on a nodal (destructive interference) or anti-nodel (constructive interference) line?

Group Two

Answer ONE of the following two questions.

6. 10 joules of elastic potential energy is stored by compressing a spring. A 2-kilogram object is placed on top of this spring and the spring released so that the object is projected straight up. If we neglect the energy dissipated in the spring, how high will be object rise? (a_g = 10 m/sec^2)

7. Show that Newton's second law $\vec{F} = m\vec{a}$ can be written $\vec{F} = \Delta\vec{p}/\Delta t$.

Directions

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$v = at$ $\qquad$ $\Delta(PE)_{(grav)} = ma_g d$

$d = \frac{1}{2}at^2$ $\qquad$ $W = F_{\parallel} d.$

$\vec{F} = m\vec{a}$ $\qquad$ $\text{power} = \frac{W}{t}$

$\vec{p} = m\vec{v}$ $\qquad$ $T = \frac{1}{f}$

$KE = \frac{1}{2}mv^2$ $\qquad$ $v = f\lambda$

1. An object at rest may have a non-zero amount of

A. momentum.
B. energy.
C. speed.
D. velocity.

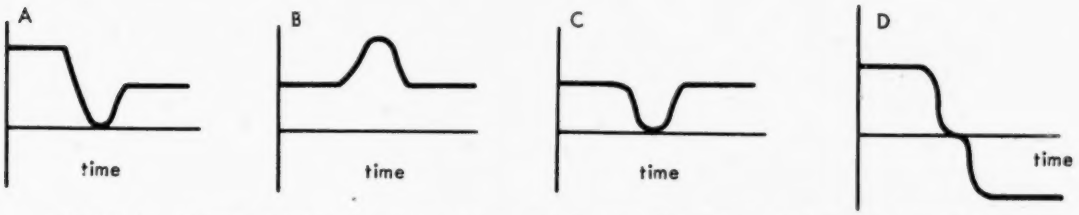
2. ALL EXCEPT ONE of the following can be adequately described by Newtonian mechanics. Which is the exception?

A. the motion of a flare dropped from an airplane
B. the relationships between observable properties of gases
C. the sizes and speeds of molecules in a gas
D. the motions of atoms inside molecules

3. The first law of thermodynamics is a statement of

A. the law of conservation of energy.
B. the law of conservation of momentum.
C. the law of conservation of mass.
D. Newton's law of action and reaction.
E. Galileo's law of motion.

The following graphs refer to items 4-7.



A ball is thrown against a wall from which it rebounds. Which of the above graphs could best represent each of the following? (Note: An elastic collision is one in which the kinetic energy is the same before and after the collision.)

4. the kinetic energy of the ball, assuming an elastic collision

5. the kinetic energy of the ball, if the collision is partly elastic

6. the magnitude of the ball's velocity during an elastic collision

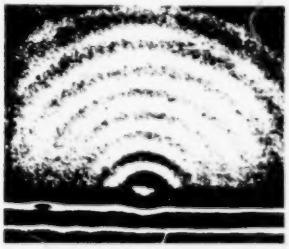
7. the magnitude of the ball's velocity during a partly elastic collision

Questions 8 to 13 refer to pictures of water ripples. Use the following key to answer questions 8 to 13.

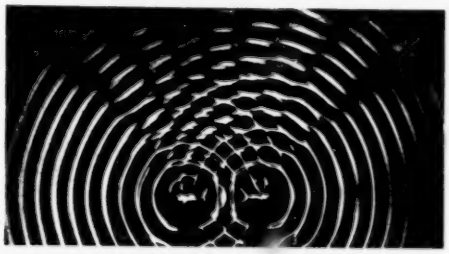
A. diffraction
B. refraction
C. reflection
D. interference

8. Which of the above is illustrated by the picture below?

9. Which of the above is illustrated by the picture below?



10. Which of the above is illustrated by the picture below?



11. The law of normal distribution applies in ALL EXCEPT ONE of the following cases. Which is the exception?

A. the heights of a large number of 25-year-old maple trees in a certain forest
B. the speed of a falling object measured at many different times during the object's fall
C. the scores on a test taken by a large number of students.

12. The second law of thermodynamics suggests that

A. energy tends to transform itself into less useful forms.
B. the usual order of natural processes is from disorder to order.
C. all natural processes are reversible.
D. it is possible to determine the motion of an individual molecule in a gas.

13. Even though one may listen to a band from a considerable distance, the sound of the piccolo and that of the tuba do not get "out of step" with each other. This is evidence that in this situation sound waves

A. travel at the same speed for all frequencies.
B. are not polarized.
C. are longitudinal.
D. tend to be sinusoidal.
E. travel at a slower speed than light.

14. All bodies contain electrical charge (which comes in two varieties, positive and negative). A law of conservation of charge applies. Which of the following might be a consequence or statement of that law?

A. Charge is rare and must be used carefully.
B. If an object with a net positive charge explodes, each of the pieces must have a net positive charge.
C. The total net charge in an isolated system does not change with time.

15. The prediction of a "heat death" is based on the principle which states that

A. the law of conservation of energy applies only to closed systems.
B. at some time in the future, the energy of the universe will become zero.
C. all bodies in the universe will eventually reach the same temperature by exchanging heat with each other.
D. it is impossible to think of a system in which energy is completely conserved.

PROBLEM-AND-ESSAY QUESTIONS

Group One.

Answer THREE of the following five questions.

1. A ball is dropped from the top of a tower (neglect air resistance). Draw two graphs showing (i) the change in the kinetic and (ii) the change in gravitational-potential energy of the ball with height.

2. The second law of thermodynamics summarizes our knowledge concerning the direction of natural processes and energy dissipation. Describe one physical phenomenon that is explained by the second law.

3. The orbit of the Alouette satellite is nearly circular and hence its speed is nearly constant. Is its momentum also constant? Explain.

4. Lavoisier observed chemical reactions in closed containers and carefully weighed the containers and their contents before and after the reactions.

   a. What were the results of such experiments?
   b. What was the significance of these results?

5. The kinetic theory of gases uses a model of a gas that assumes that gases consist of large numbers of very small particles (molecules) in rapid disordered motion. What is one consequence of assuming that the motion of the particles is disordered?

Group Two

Answer ONE of the following two questions.

6. Some seventeenth-century pholosophers insisted that the idea of a universe running down was incompatible with the idea of the perfection of God. They held that if motion was correctly defined, it could be shown that the amount of motion in the universe is constant.

   Was the law of conservation of momentum compatible with the beliefs of these seventeenth-century philosophers? Explain.

7. A hunter returned from safari in Africa and told the following tale: "Suddenly a lion jumped at me. I quickly fired my rifle. The bullet struck the lion while he was in the middle of his jump, and he fell straight down to the ground." Do you believe this? Explain, with reference to the appropriate law or laws of conservation.

Test C

Directions

Answer all 40 multiple-choice questions by marking the letter corresponding to the one best answer.

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$W = F_{\parallel} d.$

$\text{power} = \frac{W}{t}$

$T = \frac{1}{f}$

$v = f\lambda$

1. Which of the following is a vector quantity?

A. momentum
B. kinetic energy
C. work
D. heat
E. temperature

2. A 10-kilogram weight is dropped from a height of 3 meters. Just before striking the ground the weight's kinetic energy will be about

A. 3 joules
B. 30 joules
C. 300 joules
D. 3000 joules

3. A number of the examples of the energy concept make use of "frictionless" systems. Why is this done?

A. Most systems are frictionless.
B. Total energy is not conserved when friction is present.
C. Friction is not as meaninful a concept as energy.
D. Friction is not present in outer space.
E. It is often possible to get useful answers by ignoring friction.

4. Which one of the following is most nearly an "elastic" collision?

A. two railway cars coupling
B. an automobile collision
C. two billiard balls colliding
D. an apple dropped on the ground
E. a hammer hitting a nail into wood

5. When the displacement pattern of a transverse wave lies in a single plane, the wave is said to be

A. reflected.
B. polarized.
C. diffracted.
D. refracted.

6. Two steel balls collide elastically.

A. Momentum is the same before and after the collision, but kinetic energy is not.
B. Momentum and kinetic energy are the same before and after the collision.
C. The temperature of both balls will increase.
D. The balls will be permanently deformed.
E. The balls will stick together.

7. ALL EXCEPT ONE of the following can be adequately described by Newtonian mechanics. Which is the exception?

A. the motion of a flare dropped from an airplane
B. the relationships between observable properties of gases
C. the sizes and speeds of molecules in a gas
D. the motions of atoms inside molecules

8. The law of normal distribution applies in ALL EXCEPT ONE of the following cases. Which is the exception?

A. the heights of a large number of 25 year old maple trees in a certain forest
B. the speed of a falling object measured at many different times during the object's fall
C. the scores on a test written by a large number of students

9. The second law of thermodynamics suggests that

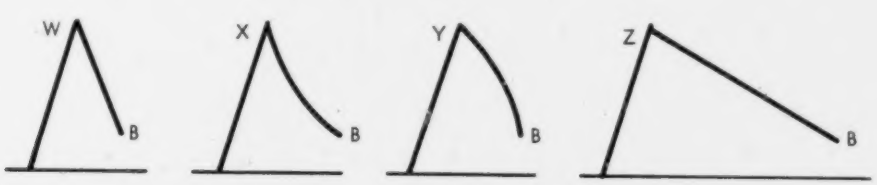
A. energy tends to transform itself into less useful forms.
B. the usual order of natural processes is from disorder to order.
C. all natural processes are reversible.
D. it is possible to determine the motion of individual molecules in a gas.

10. Some men feeling the need for exercise organize a baseball game. The first batter hits a waist-high pitch over the center fielder's head.

One of the following statements about the ball during its flight is FALSE. Which one?

A. The higher the ball goes, the greater its gravitational potential energy.
B. The horizontal component of the ball's velocity is constant.
C. The total energy of the ball is constant.
D. the momentum of the ball is constant.

11. A girl wants to slide down a playground slide so that she will have the greatest possible speed when she reaches the bottom (point B). Which of the following <u>friction-less</u> slides should she choose? (Points W, X, Y, Z are all two meters above the ground, and point B is 0.5 meters above the ground.)



A. slide W
B. slide X
C. slide Y
D. slide Z
E. The speed at B will be the same for each.

12. Leibniz's *vis viva* most closely resembles

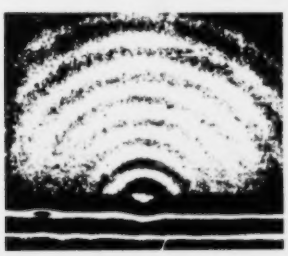
A. potential energy.
B. kinetic energy.
C. heat.
D. velocity.
E. momentum.

Questions 13 to 15 refer to pictures of water ripples. Use the following key to answer questions 13 to 15.

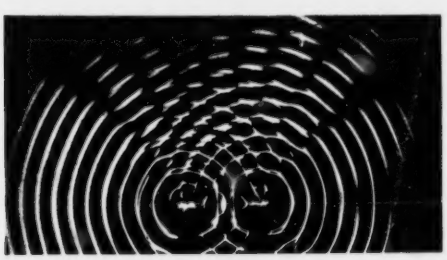
A. diffraction
B. refraction
C. reflection
D. interference

13. Which of the above is illustrated by the picture below?

14. Which of the above is illustrated by the picture below?

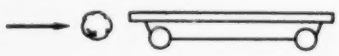


15. Which of the above is illustrated by the picture below?



Questions 16 and 17 refer to the following statement:

A 0.1 kilogram snowball strikes a 0.9 kilogram stationary skateboard and sticks to it. At the instant of impact, the snowball has a velocity of 18 meters per second in the horizontal direction. (Assume that the skateboard is on a perfectly horizontal stretch of ground and that it moves without friction.)



16. After collision, the skateboard and snowball move horizontally with a velocity of

A. 1.8 m/sec.
B. 2 m/sec.
C. 16.2 m/sec.
D. 18 m/sec.
E. 180 m/sec.

17. Kinetic energy is not conserved in the above collision because

A. the system is not closed.
B. the collision is not perfectly elastic.
C. momentum and energy cannot both be conserved in a collision.
D. the law of conservation of energy does not hold for a frictionless system.
E. heat cannot flow from a cold object to a hot object.

18. An object is hung on a vertical spring and allowed to oscillate up and down. At any instant the system's total energy is

A. $KE + PE_{elastic} + PE_{gravitational}$
B. $KE + PE_{elastic}$
C. $KE + PE_{gravitational}$
D. $PE_{elastic} + PE_{gravitational}$
E. KE

19. Which one of the following is transferred from one place to another by a propagating wave?

A. mass
B. energy
C. time
D. velocity

20. A body's momentum is defined as the body's mass times its velocity. The mks unit of momentum is

A. kilogram-meter.
B. kilogram-meter/sec.
C. kilogram-meter^2/sec^2.
D. kilogram^2-meter/sec.
E. none of the above.

Questions 21, 22, and 23 are the names of scientists who made early significant contributions to the study of thermodynamics, Select the one statement that best describes a contribution of the particular scientist.

A. the pressure of a gas is proportional to the square of the speed of its molecules
B. heat is a form of energy
C. the speeds of molecules in a gas follow a statistical law
D. in an elastic collision, momentum is conserved
E. the process of equalization of temperatures by the flow of heat from hot to cold objects is always taking place in nature

21. Joule

22. Carnot

23. Maxwell

24. A girl lifts a bowling ball from the floor and places it on a rack. If you know the weight of the ball, what else must you know in order to calculate the work she does on the ball?

A. mass of the ball
B. value of a_g
C. height of the rack
D. the time required
E. nothing else

25. ALL EXCEPT ONE of the following are in agreement with Goethe's nature-philosophy. Which one is the exception?

A. The methods of mechanistic science—for example, mathematical analysis and experimentation—give the wrong idea of nature.
B. Nature as it really is can be understood by direct observation.
C. One should search for the inner meaning of nature.
D. Laws that are practical and quantitative can best describe nature.

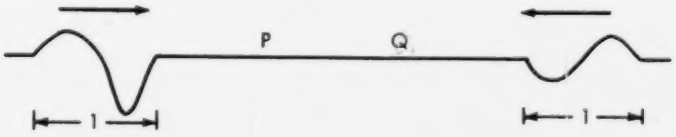
26. The kinetic energy of an object is increased the most by doubling its

A. mass.
B. temperature.
C. volume.
D. density.
E. speed.

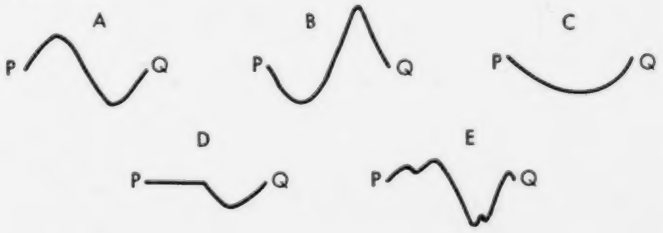
27. The first law of thermodynamics is a statement of

A. the law of conservation of energy.
B. the law of conservation of momentum.
C. the law of conservation of mass.
D. Newton's law of action and reaction.
E. Galileo's law of motion.

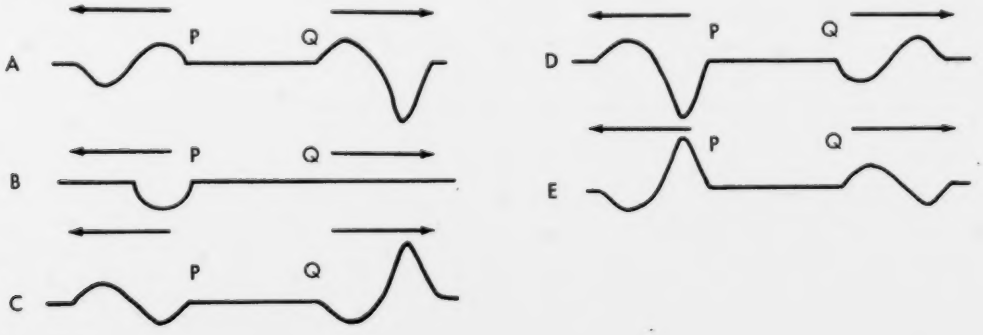
Questions 28 and 29 refer to the following statement and diagram. Two wave pulses, each of length l, are traveling toward each other along a rope as illustrated in the diagram below.



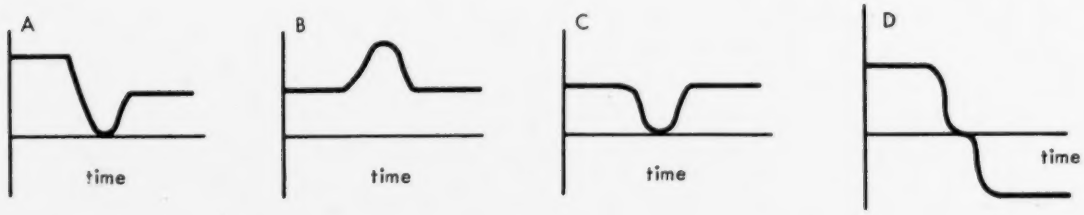
28. At the instant that both waves are entirely in the region between P and Q, the shape of the rope will be



29. Just after both wave pulses have passed the region between P and Q, the shape of the rope will be



The following graphs refer to items 30-33. A ball is thrown against a wall from which it rebounds. Which of the graphs below could best represent each of the following? (Note: an elastic collision is one in which the kinetic energy is the same before and after the collision.)



30. the kinetic energy of the ball, assuming an elastic collision

31. the kinetic energy of the ball, if the collision is partly elastic

32. the magnitude of the ball's velocity in an elastic collision

33. the magnitude of the ball's velocity in a partly elastic collision

34. The principle of superposition states that

A. the amplitudes of waves which coincide at a point may be added.
B. the wavelength of a reflected wave equals the wavelength of the incident wave.
C. every point on a wave front may be considered to behave as a point source of waves.
D. the diffraction pattern depends on the ratio of the wavelength to the slit width.

35. The prediction of a "heat death" is based on the principle which states that

A. the law of conservation of energy applies only to closed systems.
B. at some time in the future, the energy of the universe will become zero.
C. all bodies in the universe will eventually reach the same temperature by exchanging heat with each other.
D. it is impossible to think of a system in which energy is completely conserved.
E. heat must flow from a cold object to a hot object.

36. Even though one may listen to a band from a considerable distance, the sound of the piccolo and that of the tuba do not get "out of step" with each other. This is evidence that in this situation sound waves

A. travel at the same speed for all frequencies.
B. are not polarized.
C. are longitudinal.
D. tend to be sinusoidal.
E. travel at a slower speed than light.

37. Two spheres of the same diameter, one of mass 5 kilograms and the other of mass 10 kilograms, are dropped at the same time from the top of a tower. When they are 1 meter above the ground, the two spheres have the same

A. momentum.
B. kinetic energy.
C. potential energy.
D. total mechanical energy.
E. acceleration.

38. When a gas is held at a constant temperature, its molecules

A. have a certain constant average energy.
B. all have the same energy.
C. all have different energies that remain constant.

39. The unit "horsepower" is a measure of

A. force.
B. work.
C. work per bushel of coal.
D. work per unit time.
E. work per steam engine.

40. In 1620 Francis Bacon wrote: "There is nothing more true in nature than the twin propositions that 'nothing is produced from nothing' and 'nothing is reduced to nothing'...the sum total of matter remains unchanged, without increase or diminuation." This statement implies which of the following basic scientific principles?

A. conservation of momentum
B. conservation of *vis viva*
C. conservation of mass
D. conservation of mechanical energy
E. conservation of charge

Directions

This test consists of 8 questions in two groups. Answer only FOUR of the five questions in Group One, and only TWO of the three questions in Group Two. Spend about 5 minutes on each of the questions from Group One, and 10 minutes on each of the questions from Group Two.

NOTE:
The numerical values of some physical constants, definitions of certain units, and equations that may be useful in this test are given below.

Physical Constant:

Acceleration of gravity; $a_g = 10$ meters/second^2

Physical Units:

$$1 \text{ newton} = \frac{1 \text{ kilogram-meter}}{\text{second}^2}$$

$$1 \text{ joule} = 1 \text{ newton-meter or } \frac{1 \text{ kilogram-meter}^2}{\text{second}^2}$$

$$1 \text{ watt} = \frac{1 \text{ joule}}{\text{second}}$$

Equations:

$v = at$ $\qquad$ $\Delta(PE)_{(grav)} = ma_g d$

$d = \frac{1}{2}at^2$ $\qquad$ $W = F_{\parallel} d.$

$\vec{F} = m\vec{a}$ $\qquad$ $\text{power} = \frac{W}{t}$

$\vec{p} = m\vec{v}$ $\qquad$ $T = \frac{1}{f}$

$KE = \frac{1}{2}mv^2$ $\qquad$ $v = f\lambda$

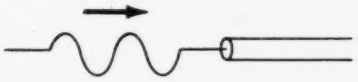
Group One

Answer FOUR of the five questions in this group.

1. The speed of sound in air at normal temperatures is about 340 meters per second. If the musical note A has a frequency of 440 cycles per second, what will be the length of the wave in air representing this note?

2. Why is the mass more appropriate than volume as a measure of an object's "amount of matter?"

3. Two pulses are sent down a thin light rope which is joined to a heavy thick rope as shown in the figure below. Describe the pulses after they have passed through the junction into the thick rope.



4. A soft rubber ball thrown against a brick wall strikes the wall and bounces back. Is the ball's momentum the same before and after collision? Is its kinetic energy the same before and after the collision? Explain what happens to the ball's original momentum and kinetic energy.

5. How does the kinetic theory of gases explain the fact that a gas expanding while pushing a piston cools, whereas a gas expanding into a vacuum does not change temperature.

Group Two

Answer TWO of the following three questions.

6. Two fishermen sit facing each other at opposite ends of a canoe on a quiet pond. One man tosses a heavy lunch box to the other man.

Make use of the law of conservation of momentum to explain the motion of the boat

A. while the lunch box is in the air, and
B. after the lunch box is caught by the other man.

7. The efforts to improve the efficiency of steam engines have produced new ideas of importance to the study of physics. Discuss one of these by-products.

8. In what way did Goethe's nature-philosophy influence the discovery of the law of conservation of energy? Explain.